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Hole Detection and Energy Efficient Hole Healing for Wireless Sensor Networks

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Abstract— In wireless sensor network to maximize the sensing area is one of the research topics in these days. Since sensor nodes are deployed randomly, energy depletion or failure of nodes will cause communication voids or coverage holes. This paper aims to address the problem of hole detection and healing in mobile WSNs. We identify four key elements that are required for ensuring effective coverage in mobile WSNs: determining the boundary of the Region of Interest (RoI), finding coverage holes and its boundary, determining the best target locations to relocate mobile nodes to repair coverage holes, and to relocate mobile nodes to the target locations . We propose a lightweight, energy efficient comprehensive solution, which addresses all of the aforementioned elements for effective coverage. It operates in two steps. First is Hole Detection (HD) to identify the boundary nodes and discover coverage holes. Second, is Hole Healing with respect to remaining residual energy. In this healing approach, we are only considering nodes with energy level above the threshold value located at an appropriate distance around the hole. The proposed algorithm shows a high packet delivery rate, less packet drop ratio and gives longer life to the network by using energy of the nodes in an efficient manner

Keywords— coverage holes, energy efficient, hole detection, hole healing

I. INTRODUCTION

A wireless sensor network is composed of tiny sensor nodes each capable of sensing some phenomenon, doing some limited data processing and communicating with each other [1].Each sensor can made cover particular area only. So when a group of sensors communicate each other, then they can accomplish a task efficiently by sensing the whole target region.

Some of the challenges in WSNs are node deployment, energy consumption, node heterogeneity, data aggregation, and fault tolerance [1].Several problems can occur in the Wireless Sensor Network that can impair their functionality. Sensor nodes can be deployed randomly or deterministically to sense the target areas. A well planned deployment can help to maximize the sensing area. Since sensor nodes are deployed randomly, the target areas are not covered and leads to holes. Hole detection is one of the major fundamental issue since it identifies damaged, attacked or out of coverage nodes in the network .If there is a hole in the network then data will be routed along the hole boundary nodes again and again which will lead to premature exhaustion of energy present at these nodes [3].Thus the Holes affect the network capacity and coverage of the network.

Coverage holes are the result of unplanned deployment of nodes because of which target area is not covered properly. They may also occur due to changing topology which make some sensor nodes to move over time ,leading to coverage holes[3].If coverage holes are not detected, the data is not been unreported or sensed, thus the functions of network is affected. Coverage hole detection aids in identifying alternative communication pathways and assists in regulating data traffic flow [2].

This paper seeks to address the problem of hole detection and healing in a different perspective. Most of the existing solutions of hole detection use global operations to calculate the size of a big hole and then relocate a group of mobile sensors to heal the hole, without considering energy levels of the nodes While some existing localized solutions requires strong assumptions that every node is capable for relocation. The inspiration from the earlier works motivates the concept of local healing based on energy levels.

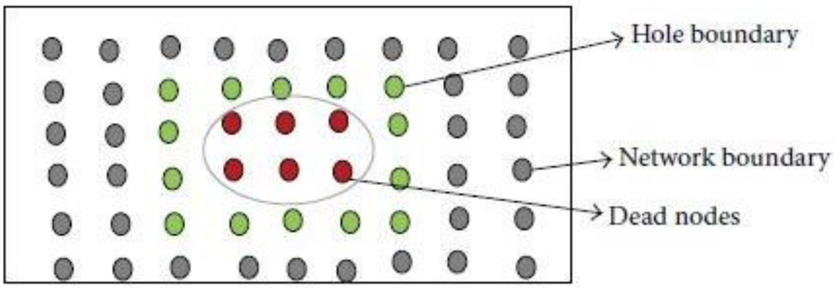

Figure 1 : Hole Boundary and Network Boundary[2]

We propose a comprehensive solution, called Hole Detection (HD) and Hole Healing. HD is a distributed and localized algorithm that operates to identify holes within the RoI.Then a Hole Healing method based on the concept for residual energy and movement of nodes within the local area.

II. RELATED WORKS

A. Hole Detection and Boundary Detection

Kun bi et al [4] proposed a distributed cooperative topological hole detection algorithm to identify those characteristics and determine those boundary nodes to identify the holes .The main idea of this distributed algorithm is to identify the characteristics of boundary node by a condition that the number of neighbours of a boundary node should be lower than that of those of non-boundary The main drawback of this algorithm is it can't be used for large WSN,with few holes and we can't identify all the boundary nodes .An algebraic topological technique using homology concept finds single overlay coverage holes without coordinates [5],[6]. Ghrist and Muhammad [6] employed a central control algorithm that needs connection details for all nodes in the RoI. For N nodes, time complexness is O (N^5).

Alexander Kroller et al[7]proposed an overall framework for self organization based on topological consideration and geometric packing arguments to determine the boundary nodes and topology of the whole network. The main objective of these algorithms and protocols is that it allow self-organization of the swarm into large-scale structures that reflect the structure of the street network, setting the stage for global routing, tracking and guiding algorithms. Main disadvantage of this paper was it deals with relatively complex combinatorial structure.

B. Coverage Solution

Zou and Chakrabarty[8] proposed a centralized virtual-force-based mobile sensor deployment algorithm(VFA), which combines the ideas of potential field and disk packing In VFA, there is a powerful cluster-head that will communicate with all the other sensors, collect sensor position information, and calculate forces and desired position for each sensor. VFA has the drawbacks of centralized algorithms, single point of failure, bottleneck of processing, and less scalability.

Z. Yong and W. Li[9] proposed Distributed Self-Spreading Algorithm(DSSA) that can cover the region of interest without any intervention from a central controller that acts remotely. The algorithm is inspired by the equilibrium of molecules, which minimizes molecular electronic energy and inter-nuclear repulsion. Each particle obtains its own lowest energy point in a distributed manner and its spacing from the other particles is almost the same. main disadvantage of this approach is that it follows the centralized approach and also maximize WSN resource consumption.

S. Ganeriwal, A. Kansal, [10] proposed a self-aware actuation for coverage maintenance in sensor networks called Coverage Fidelity maintenance algorithm (CO-Fi). We consider a network where nodes (or a subset of the nodes) can move in a controlled manner, possibly at high energy expense and this algorithm uses mobility as an adaptive actuation facility for automated deployment repair of the network with the sole objective of salvaging the lost coverage in the network. They utilize the mobility of nodes to repair the coverage loss of the area.. Main drawback of this algorithm is it does not address the problem of coverage loss due to physical damage of the hole.

P. Corke *et al* [11] proposed an energy efficient self healing mechanism for Wireless Sensor Networks. This mechanism is based on Distributed Computational Model The proposed solution is based on our probabilistic sentinel scheme. To reduce energy consumption while maintaining good connectivity between sentinel nodes, solution was composed on two main concepts, node adaptation and link adaptation

The main advantages of hole detection and healing is it minimizes resources utilization , increases the speed of healing process and conserve the initial topology.

III. PROBLEM STATEMENT

Sensor networks are mainly used for sensing and communication purposes in the real time situation, So there is the possibility that target fields are not 100 percent covered by sensor nodes due to random deployment of nodes ,creating communication voids or barrier. Thus the sensor nodes are not capable of communicating with each other creating coverage holes. Here we are considering large bounded holes, i.e. large holes that are surrounded by sensor nodes .Here we can assume coverage hole to be large bounded hole.

Our problem is to design a mechanism for detecting and recovering holes by exploiting only the nodes mobility [9].Here we are not considering healing of the holes in the boundary of the network before and after the initial deployment.

Most of the hole detection methods we are using depends on computational geometry tools such as Voronoi Diagram [14] to identify holes. But this approach can't be used in for large holes because moving of nodes without the knowledge of the other node movements may lead to creation of new holes or will not help to recover the hole problem completely and efficiently. In order to avoid these problems we are making following assumptions [12]:

- A dense mobile WSN is deployed in an obstacle free network
- Deployment can be deterministic or random.
- All the deployed nodes are homogeneous in terms of processing power, communication and energy consumption.
- Location information of the each node is known by using some localization scheme.
- Each node is aware of the boundary range information in the network
- We consider the isotropic sensing model (uniformity in all orientations).

IV. PROPOSED METHOD

In our algorithm we propose a Hole Detection mechanism (HD) to detect the hole within the network, and not on the boundaries to heal the holes. This method includes the (i) Hole Detection Algorithm and (ii) Boundary Detection Algorithm. In this approach, holes that are circumscribed by nodes are taken into account using Tent Rule[13]. The mobility feature of the nodes is been used to heal the holes. This paper covers identification of holes in the boundaries but healing of such boundary holes is been maintained as future work.

In our Hole Detection Algorithm (HDA), we need to perform the basic steps such as identifying the hole, then finding the characteristics of hole ,then finding the boundary of nodes. After that the simple healing process is invoked such that only selective nodes located within the certain range will be involved in hole healing by considering the remaining residual energy.

A. Hole Identification

Fang et al. [13] defined the stuck nodes where packets can possibly get stuck in greedy multi-hop forwarding. A node p∈S is a stuck node if there exists a location q outside the p's transmission range so that none of the one -hop neighbours of p is closer to q than p itself [12]. Fang et al. [12] developed a local rule, the TENT rule, for each node in the network to test if it is a stuck node. The TENT rule specifies that a node is not a stuck node when there is no angle spanned by a pair of its angularly adjacent neighbours greater than 120 degrees. Here every node will sends its location details to its one hop neighbours, then by comparing its one hop neighbours we could find the hole.

B. Hole Discovery

The main aim of this step is to find hole boundary and also the characteristics of hole (radius and centre).The nodes that are marked as struck nodes will check its location information against the available boundary range. As the result they differentiate themselves from the boundary nodes $\{b_o, b_1, ... b_N\}$ and struck nodes. Once a node identifies itself as a stuck node it generates a new Hole Discovery (HD) packet, marked with its ID and forwards it to the next struck This process is repeated until the HD packet has travelled around the hole and eventually been received by the forwarded node . Then, each node extracts the locations of the boundary nodes from the received HD packet. Then it selects two nodes and so that the distance between them is the longest between any two nodes in the set of boundary nodes to determine hole centre.

Distance ($(b_{m,} b_n)$ = Max {Distance $\left(b_j, b_k\right)$ / b_j, b_k

$$\subset \{b_o, b_1, ... b_N\}$$

Thus determined hole centre is the midpoint of the maximum distance and characteristics of holes, i.e. midpoint and radius is been calculated. The radius is calculated using:

$$\text{Centre}\left(x, y\right) = \begin{Bmatrix} (x_{b_m} + x_{b_n}) / 2 \\ (y_{b_m} + y_{b_n}) / 2 \end{Bmatrix}$$

C. Boundary Detection

In order to differentiate the network boundary and hole boundary we are comparing coordinate value of nodes.

D. Hole Healing - Area Determination

Hole Healing Area is the area in which healing is performed. We are calculating this area by approximating the radius of the hole. This area will determine the number of nodes required for healing. To find the appropriate radius, we are using iterative approach, using the formula,

$$R = r * (1 + \beta)$$

Where r is the hole radius

β is the positive constant that depends on density and sensing range.

E. Hole Healing with respect to energy

In this healing process, we are proposing a new method which works on both energy and distance for giving longer lifetime to the network. If we are using only shortest distance of relocation is considered, nodes nearer to the holes will be selected repeatedly resulting in their early energy loss or if only the nodes having maximum energy are selected, then longer distance may used for relocation. Therefore, a combination of energy and distance is used as a effective solution for hole healing.

First the average energy of all the struck nodes is calculated, so that we could select the nodes which are having residual energy greater than a threshold value .Then, the hole healing area is calculated so that the nodes to could be relocated for effective coverage. Then we are applying some movement to hole healing area such a way that all the nodes gets relocated . The proposed method selects the next node to be relocated by utilizing energy in an efficient manner and also deals with the problem of routing holes also. By doing this, packet dropping rate decreases.

V. SIMULATION RESULTS AND ANALYSIS

The hole detection and energy efficient hole healing can be implemented by using NS2 .Table 1, shows the simulation parameters for the experimental setup.

TABLE I SIMULATION PARAMETERS

Parameters	**Value**
Number of Nodes	50
Propagation Models	Two way ground
Antenna Model	Omni directional
Initial Energy	50 J
Routing Protocols	Wireless Channel
Network interface Channel	500

Simulation analysis can be represented based on the different criteria:

- **Throughput**

Network Throughput refers to the volume of data that can flow through a network. In fig 2 green curve has higher throughput than existing hole healing method.

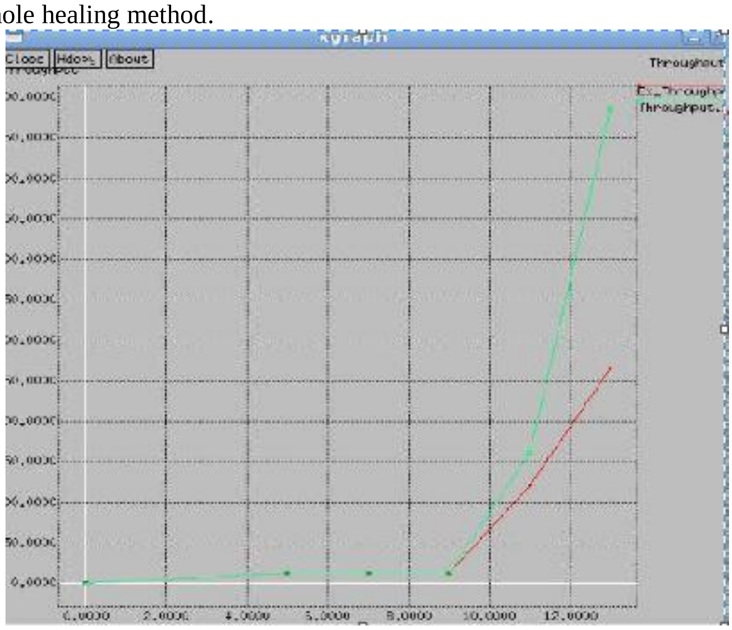

Figure 2: Throughput

- **Packet delivery ratio**

The packet delivery ratio can be defined as total number of packets received by total number of packets sent. In Packet Delivery Ratio (PDR) graph the x-axis indicates time and y-axis indicates the packet delivery ratio values, it should be within 0 to 1.In figure 3, there is lesser packet loss during transmission in comparison with existing hole healing method.

Figure 3: packet delivery ratio

- **Packet drop**

Packet drop is defined as number of packets dropped during the transmission.

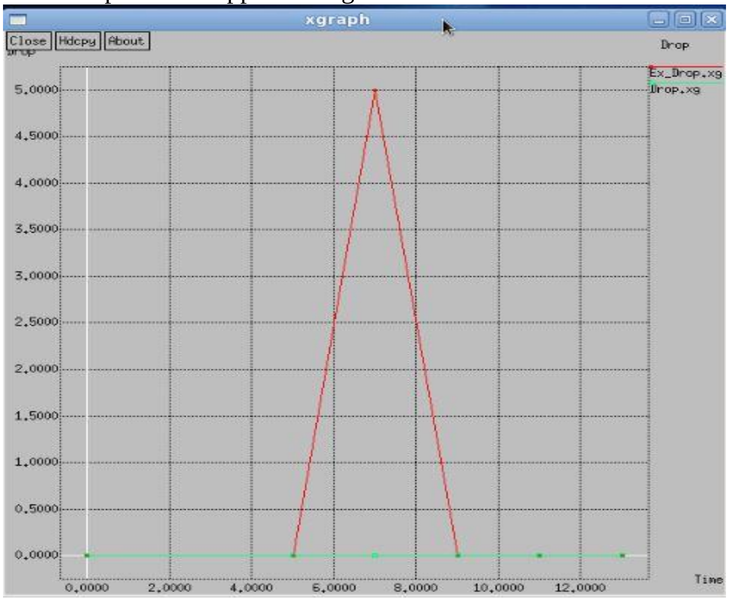

Figure 4: Packet drop

VI. CONCLUSION

This paper has proposed and implemented a coverage hole detection and energy efficient hole healing in ns2. To remove the drawbacks of existing method, a modified hole detection and healing method based on average energy and shortest relocation distance.. Thus providing energy and cost efficient Hole detection and Healing method. Then performance is evaluated in terms of packet drop, packet delivery ratio and throughput in ns2. Here we are only dealing with bounded holes in network and also hole in the network boundaries are not considered .So, it could taken as the future work. Then performance is evaluated in terms of packet drop, packet delivery ratio and throughput

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